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THE DETECTION OF LATERAL MOTION BY U.S. NAVY JET PILOTS

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The present report evaluates a lateral motion detection test as a vision standard for naval aircrew personnel selection. The leftward and rightward threshold velocities of a 1.5-degree spot of light presented in an essentially empty visual field were measured in 110 U.S. Navy fighter pilots. These threshold measurements were compared to similar measurements of nonaviator subjects as reported in the literature. There was no evidence that pilots and nonpilots differed. Air-to-air target detection distances measured during air combat maneuver training were compared to the aviators' velocity thresholds. The statistical evidence of a relationship between the vision and the performance measure was ambiguous and most likely due to sampling effects. Correlation between pilot age and velocity thresholds was not statistically significant. This particular test of lateral motion holds little promise as a useful, practical tool for personnel selection.

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SUMMARY PAGE

THE PROBLEM

The present paper reports a study of lateral motion detection capabilities of U.S. Navy fighter pilots. The research is part of a project designed to identify and evaluate tests of visual skills useful as valid, practical, performance-based standards for the selection and retention of Navy and Marine Corps aircrew personnel. The leftward and rightward threshold velocities of a small spot of light presented in an essentially empty visual field were measured in 110 U.S. Navy jet pilots. These measurements were compared to similar measurements of nonaviator subjects as reported in the literature.

FINDINGS

There was no evidence that the pilots and nonpilots differed, although there was only a small sample of subjects available from the literature. Air-to-air target detection distances measured during air combat maneuver training were compared to the aviators' velocity thresholds. The statistical evidence of a relationship between the vision and the performance measures was ambiguous, and additional data would be necessary to evaluate this relationship. The correlation between the age of the pilots and their velocity thresholds was not statistically significant.

RECOMMENDATIONS

This particular test of lateral motion holds little promise as a useful, practical tool for personnel selection and retention and does not warrant further investigation for this purpose.

Acknowledgments

We wish to thank the commanding officer and the pilots of FITWING ONE, NAS Oceana, Virginia, for their cooperation in this project. Special recognition is given to CAPT James E. Goodson, who directed the development and planning of this project until 1982, and to CDR William A. Monaco, who directed the project from 1982-1985. Mr. Efrain Molina provided extensive engineering and technical support throughout the project.

INTRODUCTION

The Naval Aerospace Medical Research Laboratory (NAMRL) is studying U.S. naval fighter pilots to characterize aspects of vision important for the performance of tasks specific to naval aviation. The primary goal of this research is to provide empirically based visual assessment standards useful for personnel selection and retention. The subsidiary goal is to discover ways to train vision skills important for success as a naval aviator. To achieve these goals, a battery of psychophysical vision tests was designed and instrumented for use in the NAMRL mobile vision laboratory (1-3). The mobile laboratory was set up at the Tactical Air Combat Training range at NAS Oceana, Virginia Beach, and used to measure the vision of Navy fighter pilots during their duty assignment at Oceana. In this way, we were able to study the relationships between aspects of pilots' operational performance and laboratory measures of vision.

The present study reports measures on a visual task that had been included in the test battery because it seemed closely related to a vision skill thought to be important to the detection of an adversary aircraft in the air-to-air combat arena. Often during air combat maneuvers, the adversary aircraft is initially too far away to be seen. As the aircraft gets closer, it approaches the threshold of visual detection and is first seen as a small distant spot. If the adversary turns at this far distance, it will appear as a small spot of light moving slowly in one direction or another. The present paper reports measurements of the ability of fighter pilots to discriminate the slowest lateral leftward or rightward motion of a small spot of light.

METHODS

SUBJECTS

Subjects were 110 male U.S. Navy F-14 pilots ranging from 25 to 41 years of age (mean = 30.35, $\underline{SD} = \pm 4.26$). The subjects were tested binocularly and wore their prescribed corrective eye glasses if they were routinely worn while flying.

APPARATUS

The measurements were made in NAMRL's Mobile Vision Testing Laboratory set up at the Naval Air Station Oceana, Virginia Beach, Virginia. The test target was projected with Kodak Random Access projectors (RA 960). The test target was moved smoothly at slow speeds with a projector mounted on the platform of a Unislide (Series B4000; Valmex, Inc., East Bloomfield, NY). UniBlitz shutters (Vincent Associates, Rochester, NY) controlled stimulus duration.

The test target was a 1.5-deg circular spot of light projected onto the central region of a white screen positioned 5.5 m from the subject's eyes. When properly positioned, the subject saw an essentially homogenous white field of about 60 deg horizontal and 40 deg vertical. The luminance of the screen was 343 cd/m^2 (100 fL), and the luminance of the test target was 686 cd/m^2. Details of the vision test hardware are presented elsewhere (1,3,4).

PROCEDURE

Subjects were instructed to respond using a joystick to indicate the direction of motion of the slowly moving test spot. A two-alternative forced-choice psychophysical procedure was used; subjects indicated the direction of motion, either left or right, for each stimulus presentation. Threshold velocity was derived from only the ascending branch of the staircase with steps of 0.05 arcmin/s. A threshold was defined as the slowest velocity whose direction could be correctly discriminated on two successive stimulus presentations. Five leftward and five rightward velocity thresholds were measured for each subject. The test randomized stimulus direction so that for each trial a stimulus could be moving either to the right or to the left. Response accuracy and response time were recorded for each trial.

An auditory cue marked the start of a stimulus presentation. About 1 s later, the fixation target was presented as a crosshair with its intersection removed. Three seconds later, the fixation target was turned off, and the test target was presented where the crosshair intersection would have been. The target was presented for as long as 3 s. Responses turned the stimulus off if they occurred during the 3 s of stimulus presentation. The subject had a total of 8 s after stimulus onset to make a joystick response. Stimulus presentations were separated by a 3-s intertrial interval.

RESULTS

Figures 1 and 2 are the frequency histograms of leftward and rightward velocity thresholds, respectively. The mean (± *SD*) leftward velocity threshold was 0.672 ± 0.432 arcmin/s; rightward velocity threshold was 0.615 ± 0.370 arcmin/s. These two distributions were not statistically different by a matched-pair, two-tailed t test. Neither distribution was normal by a Kolomogorov D statistic (5) (leftward: $D = 0.1454$, $N = 110$, $p \leq 0.01$; rightward: $D = 0.1445$, $N = 110$, $p \leq 0.01$).

Because the threshold velocity in each direction for each subject was measured five times, a standard deviation was associated with the mean threshold velocity of each subject for each direction of motion. Figures 3 and 4 are frequency histograms of standard deviations associated with the leftward and rightward velocity thresholds, respectively. The average standard deviation of a subject's leftward thresholds was 0.199 arcmin/s (SD = ± 0.209 arcmin/s) whereas 0.151 arcmin/s (SD = ± 0.027 arcmin/s) was the average standard deviation of the subject's rightward thresholds. Although these two distributions were not statistically different by a matched-pair, two-tailed t test, subjects tended to be less variable in the direction of rightward motion.

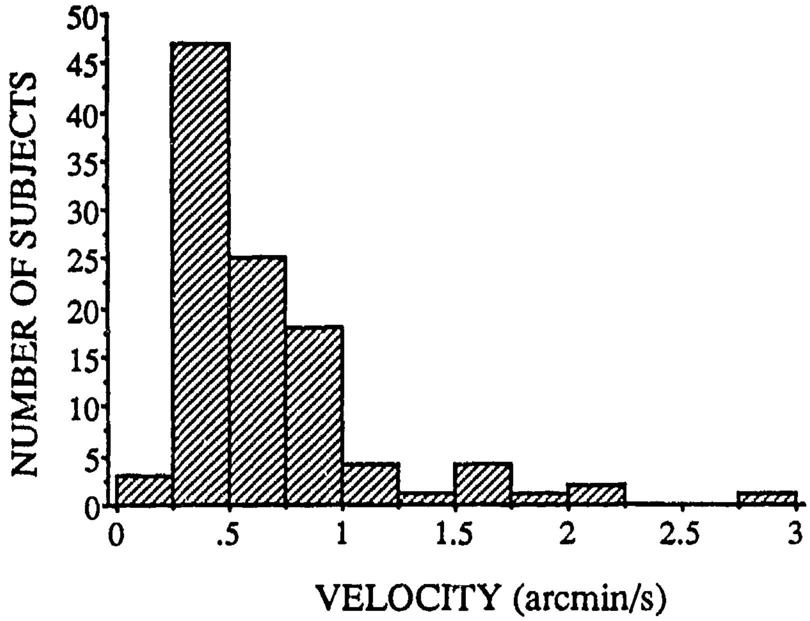

Figure 1. *Frequency histogram of leftward velocity threshold.*

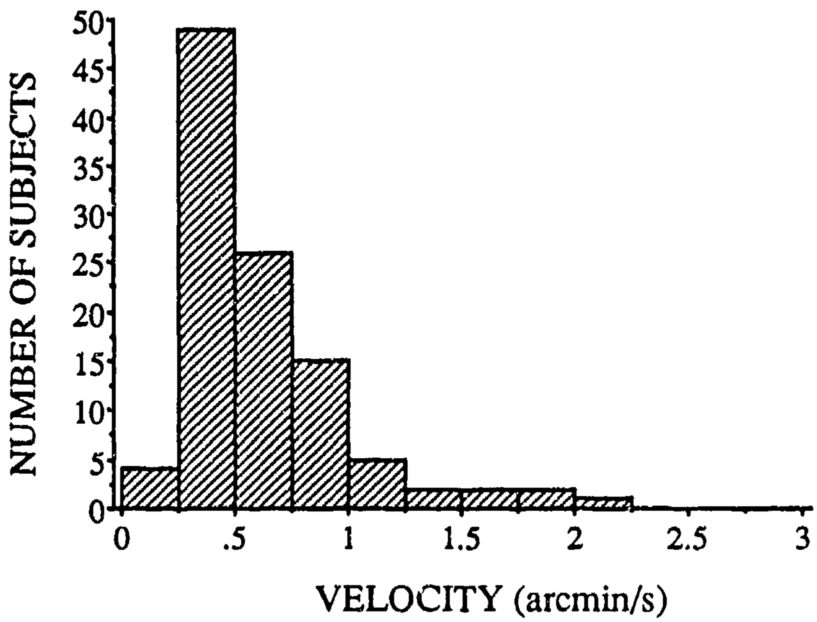

Figure 2. *Frequency histogram of rightward velocity threshold.*

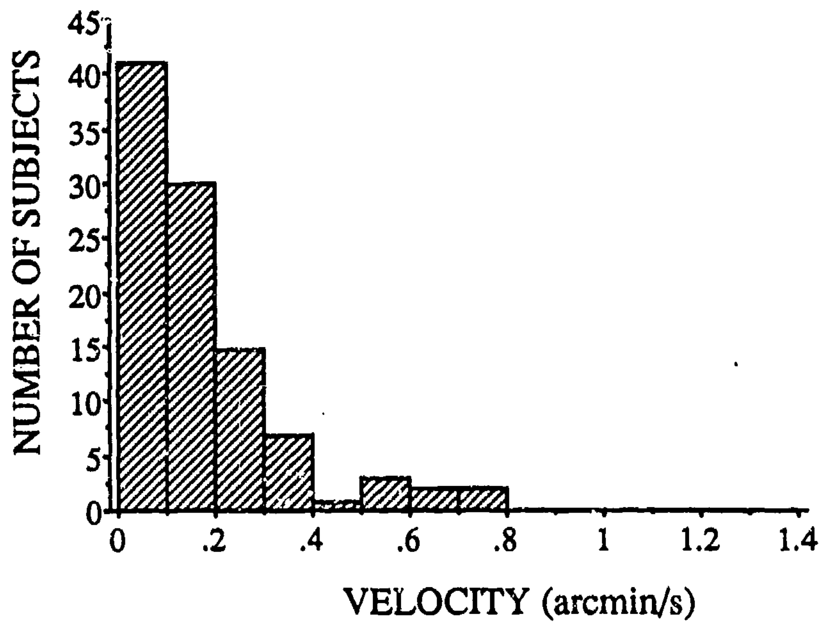

Figure 3. *Frequency histogram of the intrasubject standard deviations for five repeated leftward velocity threshold measurements.*

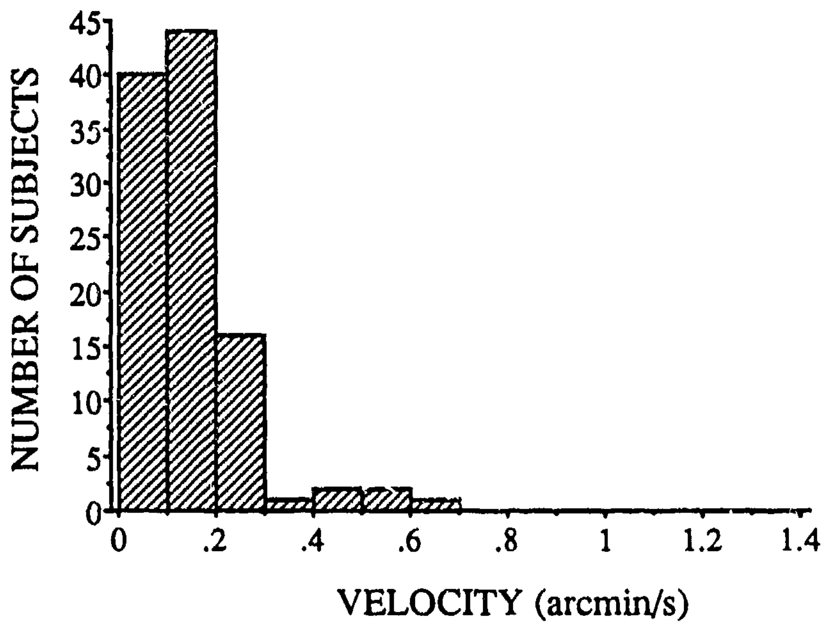

Figure 4. *Frequency histogram of the intrasubject standard deviations for five repeated rightward velocity threshold measurements.*

Figure 5 is the frequency histogram of response times to the leftward threshold velocities. This distribution had a mean (*SD*) of 1.021 s (± 0.230 s). Figure 6 is the frequency histogram of response times to the rightward threshold velocities. The mean (*SD*) of this distribution was 1.028 s (± 0.244). A matched-pair, two-tailed *t* test demonstrated that these were not statistically different distributions. The Kolomogorov D statistic (5) demonstrated that these histograms were not normally distributed (leftward: $SD = 0.1056$, $N = 110$, $p \leq 0.01$; rightward: $SD = 0.1097$, $N = 110$, $p \leq 0.01$).

Lastly, the standard deviation associated with each mean response time was obtained from the five measurements. The distribution of the standard deviations of response times to the leftward velocity thresholds is shown in Fig. 7. The mean (*SD*) of this distribution was 0.307 s (± 0.173). Figure 8 is the distribution of standard deviations of response times to the rightward velocity thresholds. The mean (*SD*) of this distribution was 0.303 s (± 0.158). A matched-pair, two-tailed *t* test demonstrated that these were not statistically different distributions.

DISCUSSION

1. *Do leftward and rightward velocity thresholds differ?*

We found essentially no evidence that the leftward and rightward velocity thresholds were different as shown by the matched-pair *t* tests reported above. Furthermore, correlation coefficients between leftward and rightward mean velocity thresholds were significantly correlated ($r = 0.214$, $N = 110$, $p = 0.0274$) as were the mean response times to leftward and rightward stimuli ($r = 0.937$, $N = 110$, $p \leq 0.0001$) and the response time standard deviations to the two directions of motion ($r = 0.604$, $N = 110$, $p \leq 0.0001$). In other words, knowledge of the subject's response to one direction of motion predicted the response to the other direction of motion.

This generalization did not hold for predicting the variability in thresholds to the two directions of motion. Threshold variability to one direction of motion was not significantly correlated to threshold variability to the other direction ($r = 0.126$, $N = 110$, $p = 0.2002$). This difference in variability was reflected in the matched-pair *t* test, reported above, suggestive of a tendency for leftward thresholds to be more variable than rightward thresholds.

The tendency toward the greater variability of rightward than leftward thresholds may reflect an underlying functional difference in the visual processing of the two directions of motion. This asymmetry may be similar to the asymmetry between the rightward and leftward span of perception that occurs during various reading tasks (6). The extent or amount of the asymmetry in perceptual span is known to be variable, depending on the requirements of the task performed (6,7).

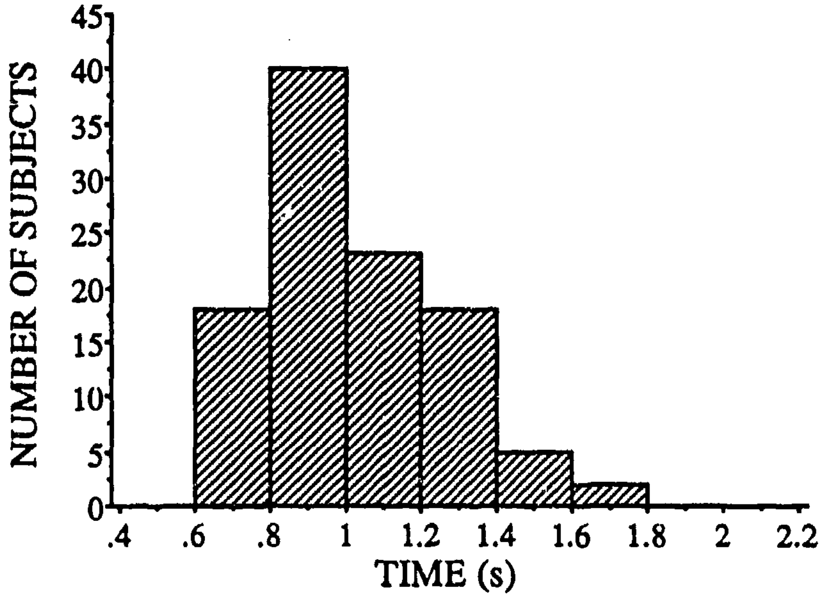

Figure 5. *Frequency histogram for the response times associated with the leftward velocity thresholds.*

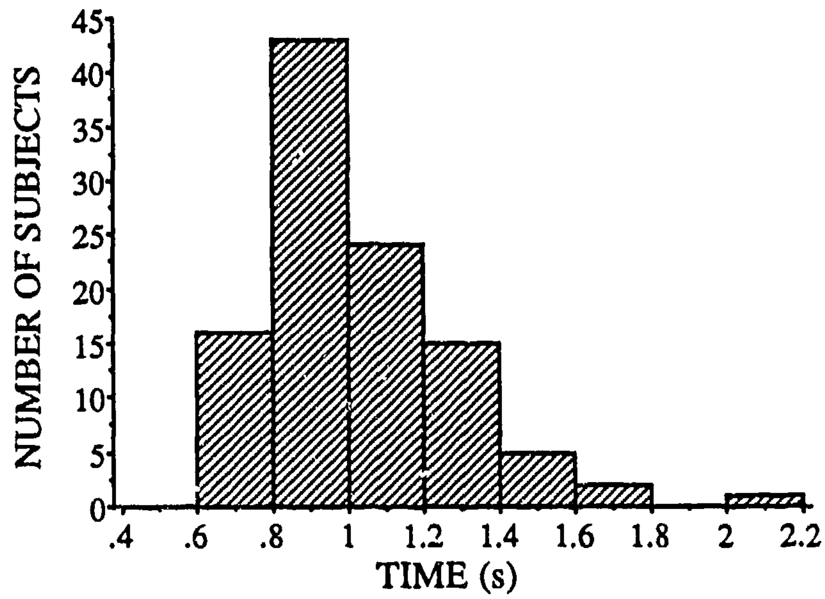

Figure 6. *Frequency histogram for the response times associated with the rightward velocity thresholds.*

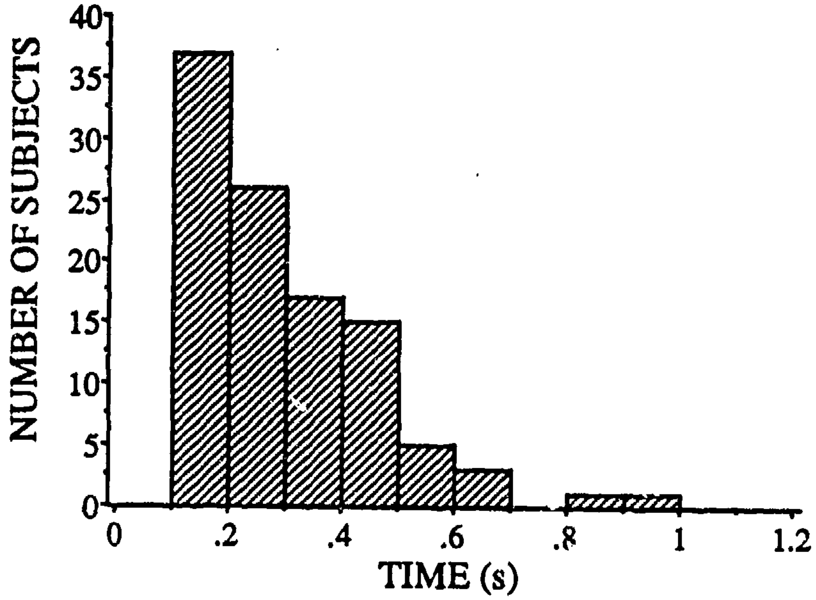

Figure 7. *Frequency histogram for the intrasubject standard deviations of the response times associated with the leftward velocity thresholds.*

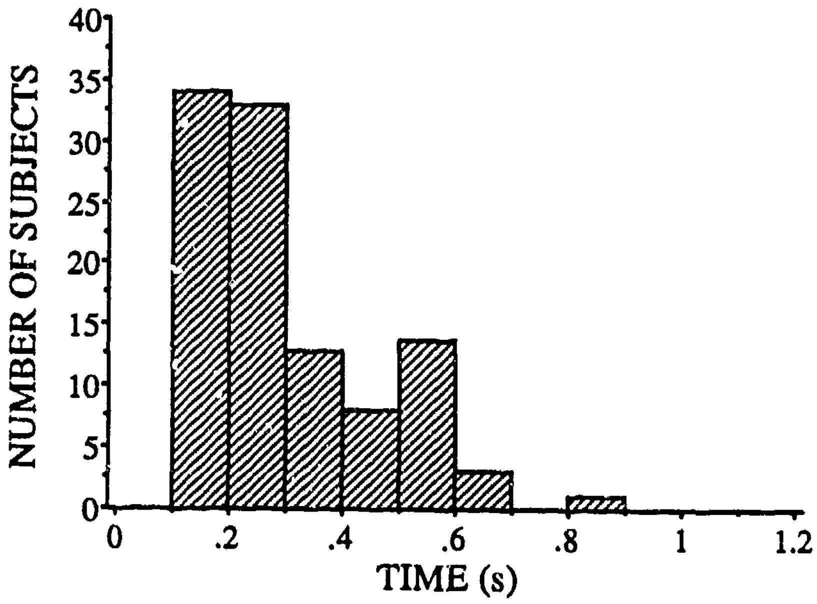

Figure 8. *Frequency histogram for the intrasubject standard deviations of the response times associated with the rightward velocity thresholds.*

This suggestion in highly speculative. Firstly, the observed difference between leftward and rightward variability was not, strictly speaking, statistically significant beyond the 0.05 probability. Secondly, the asymmetry in the span of perception has been reported in reading tasks but not in search tasks similar to the one reported here. Possibly, the appropriate studies and comparisons have not been made yet. Lastly, because the number of measurements per subject was small, a few erratic or outlying responses among a few subjects could obscure an underlying relationship, or conversely, provide spurious hints in support of an artifact. Either way, the hypothesized difference between leftward and rightward variability should be viewed as highly speculative at this time.

The above conjectures should not obscure the fact that there were significant correlations between the leftward and rightward velocity thresholds, leftward and rightward response time means, and leftward and rightward response time standard deviations. Furthermore, responses to leftward and rightward moving stimuli were not significantly different with these three response parameters.

2. *Do aviators differ from nonaviators in the performance of this task?*

Three reports in the literature (8-10) provided guidance for selecting stimulus parameters used in the present experiment. Two of the reports (9,10) were parametric studies of the dependence of the velocity threshold on such stimulus dimensions as size, shape, luminance, and duration. Although these were extensive studies exploring a large number of conditions, only three subjects were used in one study (10) and four in the other (9). In other words, the goal of these studies was not to establish norms for average or expected performance of the task but rather to identify functions relating velocity threshold to stimulus magnitude. Despite the small number of subjects, these studies provided insights into the aviator dataset simply because the studies have so well described the relationships between the stimulus parameters and threshold velocity.

The three studies demonstrated that stimulus luminance and duration are determinates of velocity threshold. In general, the longer and brighter the stimulus, the easier it is to identify the direction it moves; but for long and/or bright stimuli, the velocity threshold tends toward an asymptote. The stimulus we used was a 100 fL light presented for 3 s; a stimulus close to the asymptotic range indicated by the data of Leibowitz (10) shown in Table 1.

The threshold velocities that Leibowitz measured with a stimulus of 2.0-s duration are clearly within one standard deviation of the mean leftward and rightward velocities of the pilots (0.672 ± 0.432 and 0.615 ± 0.370 arcmin/s, respectively).

Velocity thresholds for a stimulus presented for a duration of 3.99 s were measured by Brown and Conklin and reported to be more than 10 arcmin/s (8,9). These thresholds are nearly 20 times those of the aviators. This difference in threshold is most likely due to a difference in stimulus luminance. Brown and Conklin used a stimulus of 0.026 mL, which is almost 4000 times dimmer than the one presented to the pilots. Because Leibowitz

showed that the velocity threshold is a function of stimulus luminance and found comparably large velocity thresholds for comparably dim stimuli, it is reasonable to suppose that comparably large velocity thresholds would be measured in the aviators had they had been tested with a comparably dim stimulus.

TABLE 1. Threshold velocities (minutes of arc per second) as a function of stimulus luminance and duration (Data from Leibowitz, 10).

Subject	Luminance (millilamberts)	Stimulus duration (seconds)			
		0.5	1	2	16
	0.16	6.80	1.75	1.00	0.50
	0.50	3.90	1.63	0.80	0.26
	5.00	2.80	1.74	0.80	0.48
1	50.00	3.80	1.50	0.59	0.44
	500.00	2.40	1.74	0.63	0.30
	0.16	3.50	0.83	0.54	0.31
	0.50	4.10	0.57	0.34	0.28
	5.00	3.00	0.38	0.32	0.20
2	50.00	3.00	0.31	0.32	0.25
	500.00	3.00	0.37	0.32	0.22
	0.16	6.20	2.33	1.11	0.31
	0.50	4.60	2.72	0.63	0.31
	5.00	3.40	2.03	0.59	0.28
3	50.00	3.00	1.35	0.52	0.32
	500.00	2.80	0.79	0.50	0.23

Subjects used by Leibowitz were highly skilled on this particular task. His report mentions that, at first, the subjects were highly variable in their responses and it was because of this variability that he used two correct responses in an ascending staircase as the threshold criterion (this was the same criterion that was used with the aviators). With experience, subject variability decreased. Each of his subjects was given from 5-10 practice sessions of 1-1.5 h each. The aviator subjects had never performed this task before. Most likely, the three subjects Leibowitz tested had lower velocity thresholds than the average fighter pilots because Leibowitz's subjects were so well-practiced with the task, but the fighter pilots were completely new to it.

3. *Are the lateral velocity thresholds correlated with operational performance?*

Because the aviators were tested during the time they were stationed at Tactical Air Combat Training range at Oceana NAS, Virginia, we could obtain measures of their operational performance. The distance at which the adversary aircraft was first detected was of particular interest.

The correlations between air-to-air target detection and the leftward and rightward velocity thresholds were 0.21287 and 0.00121, respectively. The former was statistically significant ($N = 91$, $p = 0.0428$) whereas the latter was not ($N = 91$, $p = 0.9909$).

With no theoretical reason for sensitivity to leftward motion to be more relevant operationally than sensitivity to rightward motion, these results are impossible to interpret without additional data. Until further work is conducted relevant to this observation, the significant correlation should be attributed to chance.

4. *Is lateral motion sensitivity dependent upon subject age?*

Because age affects a number of visual skills in the general population (11) and, to a lesser extent, in the naval aviator (12), leftward and rightward lateral velocity thresholds were correlated with age. The Pearson correlations with age for the leftward and rightward velocities were 0.64 and 0.67, respectively. Neither was significant, so age was probably not a factor determining the performance of this task by the fighter pilots.

CONCLUSIONS

The test for visual motion sensitivity described in the present paper should not be pursued further as a tool for military aviation personnel selection or retention for several reasons. Because fighter pilots and the general population performed similarly on this test, the visual skills assessed by this test are of little or no importance as a selection tool. Furthermore, the test was time consuming to administer and incorporated large training effects as mentioned by Leibowitz. Lastly, the correlation between the vision test performance and air-to-air target detection distances was ambiguous; the weak relationship observed was probably as a chance occurrence. There was little evidence for a difference in response between the two directions of motion and no evidence that the visual task was age-dependent in any way. Therefore, further research efforts on vision tests designed for the selection and retention of aviation personnel should concentrate on tests of other vision skills.

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